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Countdown timers, video surveillance and drivers' stop/go behavior: Winter versus summer

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ABSTRACT

This paper presents an analysis of drivers' stopping and traversing behaviors during inter-green periods. Eight intersections were observed in Changchun, China both with and without countdown timers and/or video surveillance during summer and winter. The impacts of the devices on the drivers' behavior were examined and compared between the two seasons from a safety perspective. During winter abrupt braking on icy road can be very dangerous. The analysis was performed by dividing the approach leg into 10 m intervals up to 90 m upstream from the stop line. Three impacts are studied, including the profile of approaching speeds, the stop/go decision, and the maximum acceleration and deceleration. The findings revealed that installing both a countdown timer and CCTV in summer, or either of the devices in winter can increase drivers' stopping tendency and hence reduce red-light violations. Especially on an icy road during winter, a countdown timer can help smooth decelerations, which tend to begin earlier than at the intersections without the device, reducing the incidence of sudden braking.

1. Introduction

During a signal phase transition from green to red, drivers entering into a signalized intersection face a complex decision on whether to stop or to continue through the intersection. A wrong decision may cause an accident such as rear-ending another vehicle or angle collisions. In Japan, for example, almost 60% of accidents every year occur at intersections or in their vicinity (National Police Agency, 2007), and red light running violation ranks as the second most common cause of accidents categorized as begin the result of dangerous driving (Ministry of Justice, 2011). Red light violations are still regularly recorded although a yellow light is used to warn drivers of an imminent phase change. Elmitiny et al. (2010) summarized the types of red light violators including three groups of people: 1) drivers who should have cleared the intersection before red but were delayed by their own decision or by slower traffic in front of them, 2) drivers in dilemma zone, and 3) aggressive drivers who could have stopped but chose to run the red light deliberately. Especially, heavy vehicles are more likely to run a red light than passenger cars (Gates et al., 2007).

Many Asian countries such as China and Thailand try to control red light violation problems by the installation of countdown timers for drivers. Countdown timers for drivers can be categorized into two types: green signal countdown display (GSCD) and red signal countdown display (RSCD). Several previous studies have reported both the positive and negative effects of the countdown timers. Especially, the positive impact of GSCD is still a matter of controversy. Thus impacts are, for example, a reduction of red light running violations although in a short term (such as in the works of Kidwai et al. (2005), Lum and Halim (2006), Zhang et al. (2010)), and Limanond et al. (2010)). However, a totally opposite impact was also found in the works of Long et al. (2011) and Chen et al. (2009). A more detailed of these works follows in the next section.

Adverse weather conditions are an important factor in traffic accidents and influence driver behavior (Kilpelainen and Summala, 2007). During winter snow, crash rates increase significantly compared to non-snow conditions (Khattak and Knapp, 2001). Since drivers behave differently in snowy conditions; the impact of countdown timers on drivers is expected to be different from that during the summer season. In particular, abrupt braking at a red light on an icy road may cause a serious accident. However, there is still lack of research on this issue. Thus, this study compares the impacts of countdown timers during summer and winter. The observations of the actual implementation of countdown timers were performed in Changchun, China. This city is the capital city

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of Jilin Province, located in the northeast of China. Changchun is a large city with more than 7 million inhabitants and is the national base for the automobile industry. Winters in this city are very cold and windy with an average temperature of below −10 °C in January. Roads are generally icy and slippery during winter.

In this study, the decision making during the phase transition is explored in detail and compared between the two seasons. The analysis focuses mainly on a safety perspective; the speed profile analysis, the maximum acceleration/deceleration. Eight signalized intersections with and without the installation of countdown timers were studied. The data was collected by a method that can gather the speed profile of vehicles (at every 10 m mark, from 90 m before the stop line), traversing and stopping behavior, acceleration, and other impacts of the countdown timers on drivers. The analysis focuses on the drivers' decisions and their responses when deciding either to stop or to continue through the intersection during the transition of phase from green to red. In addition, in some countries such as China, video surveillances (CCTV) are often installed at intersections to observe and control traffic violations. Thus, the effects of the camera are analyzed together with that of the countdown timer.

In Section 2, previous studies are summarized. Next, the data and the method of collection and the characteristics of the intersections are described in Section 3. Then, the analysis of the speed profile of approaching vehicles during the inter-green period is presented in Section 4. Comparisons are drawn between those who decided to pass through and those who decided to stop at the intersection. In Section 5, the maximum acceleration and deceleration and their location is studied to ascertain where the drivers responded to the signal device. Statistical analyses of the behavior are presented. Finally, our findings and suggestions for future studies are summarized in the last section.

2. Previous studies

In order to assist driver decision-making during the critical phase transition, several driver warning indicators have been implemented such as a traffic light change anticipation systems (TLCAS). The development of TLCAS began with a flashing signal phase in which the signal of the current color is flashed (or sometimes the color of the next phase is flashed simultaneously with the current phase color) for a few seconds before the onset of the next signal phase in order to alert drivers to the upcoming phase change. The work of Koll et al. (2004) is an example of research on the real world application of the flashing signal system. Driver behavior with and without the flashing green before yellow was analyzed based on surveys at 10 locations in Switzerland, Austria, and Germany. However, the results showed that the flashing green phase had an unsatisfactory effect. This was due to the flashing green phase widening the time period when drivers were indecisive, resulting in an increase in the number of early stops as drivers tended to underestimate the duration remaining to the end of the yellow light. This increase in early stops led to an increase in rear-end collisions.

The countdown timer is a more recent development of TLCAS. The countdown timer shows the time remaining until the onset of the upcoming signal phase as a number in seconds displayed together with the signal light. This technique provides the remaining phase time to drivers and hence the exact timing when the upcoming phase change will occur. The device is considered to assist the drivers' decision making as drivers are able to make decisions earlier, resulting in a reduction of sudden acceleration or breaking, both of which may cause traffic accidents. In general, two types of countdown timers can be found: one for pedestrians and another for drivers. In countries such as Japan and the US, the pedestrian countdown timer is rather common, especially at urban intersections. The purpose is to alert crossing pedestrians to the remaining green time, mainly for safety reasons (Murata et al., 2007). In the US, the countdown timer for pedestrians has been reported having positive effects from a safety perspective (Chen et al., 2009). The countdown timer for pedestrians has an influence on drivers' decisions as well. Huey and Ragland (2007) compared driver behavior at two intersections in Berkley, US: one with and one without the pedestrian countdown timer. Their findings indicated that drivers at the pedestrian countdown intersection were less likely to enter the intersection at the end of the drivers' yellow phase, as the timer made extra information available to drivers on the signal phase. Similar effects were found in the work of Schmitz (2011) in which the impacts of the pedestrian countdown timer on both pedestrians and drivers were observed at two signalized intersections in Lincoln, Nebraska: one with and another without the timer. The findings indicated that the pedestrian countdown timer increased pedestrian walking speed by 0.2 ft/s, while vehicle speed at the stop line during the drivers' amber phase decreased by 1.0 mi/h.

Countdown timers for drivers have a number of variations; for example, externally-hung timers (such as in China and Thailand) and built-in timers (such as in Taiwan). The externally-hung timer is a LED board displaying the timer separately from the signal light; this type of countdown timer is more common. On the other hand, the built-in timer has a timer embedded within the signal light. We recall that countdown timers for drivers are categorized into green signal countdown display (GSCD) and red signal countdown display (RSCD). Although, in most countries where countdown timers for drivers are used, both GSCD and RSCD are installed in the same intersection, however, at some locations only either a GSCD or a RSCD is installed.

Some studies reported a positive impact from GSCDs. Kidwai et al. (2005) found that although the countdown timer has little effect on capacity, a 50% reduction in the number of red light violations after the installation was observed. Lum and Halim (2006) set up a GSCD and conducted a before-and-after study on the effects of the device including before and after the installation for 1.5, 4.5, and 7.5 months. They examined whether displaying the remaining green time can reduce the proportion of red light violations. Their findings demonstrated a 65% reduction in the proportion of red light violations 1.5 months after the installation of the GSCD; however, the level of red light running bounced back to the pre-installation level in the long run. The number of vehicles stopped at the onset of yellow increased over the 1.5 months after the installation and this was sustained in the long term. Zhang et al. (2010) conducted a study on the effects of a countdown device on driver behavior during the seven days before and after the installation of a device in Beijing, China. They found that amber crossing and red light running decreased significantly after the installation of the countdown device; but these impacts may not be sustained over the long term. Limanond et al. (2010) reported, based on field observations in Bangkok a reduction of red light running during the beginning of red phase by 50%, but the timer slightly reduced the saturation flow rate during the green phase.

In contrary, an adverse effect of GSCD was also reported. A research by the Institute of Transport in Taiwan (Chen et al., 2007 cited in Chiou and Chang, 2010) showed an increased number of fatal and injury causing accidents after the installation of GSCD by 100%. This effect was explained by drivers tending to aggressively accelerate in the presence of GSCDs and thus the number of accidents increased. Chen et al. (2009) proposed the further explanation that the GSCD tended to divert the attention of some drivers from the intersection as they paid attention to the countdown timer at the expense of what was happening on the road, especially in the last few seconds. In addition, some research studies, such as Long